



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF APPEALS

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CC

re Patent Application of:)
COFFA ET AL.)
Serial No. 09/653,390)
Confirmation No. 2814)
Filing Date: September 1, 2000)
For: SEMICONDUCTOR DEVICE FOR)
ELECTRO-OPTIC APPLICATIONS,)
METHOD FOR MANUFACTURING SAID)
DEVICE AND CORRESPONDING)
SEMICONDUCTOR LASER DEVICE)
Examiner: D. WILLE
Art Unit: 2814

APPELLANTS' APPEAL BRIEF

Mail Stop Appeal Brief-Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Submitted herewith is Appellants' Appeal Brief (in triplicate) together with the requisite \$330.00 fee for filing a brief. If any additional extension and/or fee is required, authorization is given to charge Deposit Account No. 01-0484.

(1) Real Party in Interest

The real party in interest is STMicroelectronics S.r.l., assignee of the present application as recorded at reel 011395, frame 0130.

(2) Related Appeals and Interferences

There are no related appeals or interferences for the present application.

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(3) Status of the Claims

The rejection of Claims 28, 31-38 and 41-47 is being appealed. These claims are listed in the attached Appendix (9). Claims 1-27, 29-30, 39-40, 48-58 have been cancelled.

(4) Status of Amendments

All amendments have been entered and there are no further pending amendments.

(5) Summary of the Invention

The present invention is directed to a semiconductor laser device for electro-optic applications. In particular, the semiconductor laser device includes a rare-earth materials doped P/N junction integrated on a semiconductor substrate for providing a coherent light source. The doped P/N junction comprises a depletion layer and has a shape defining a waveguide, as illustrated in FIG. 9 from the Appellants' specification. The semiconductor laser device further comprises a biasing device (not shown) connected to the doped P/N junction for reverse biasing thereof.

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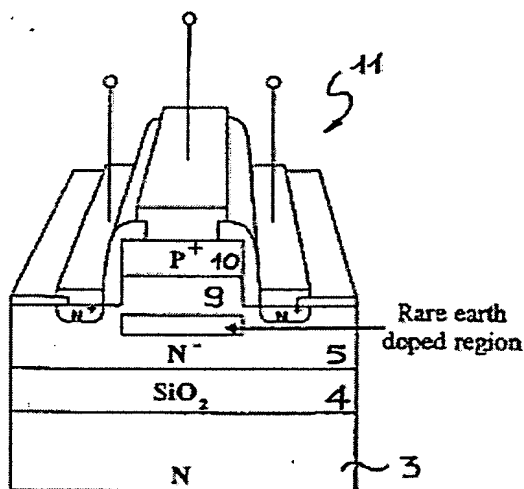


FIG. 9 from the Appellants' specification

Excitation of rare-earth materials at room temperature is a sufficient condition to be met for an LED - a device that produces an incoherent light source. This condition, although necessary, is not sufficient to achieve a laser device - a device that produces a coherent light source. The present invention advantageously provides a combination of the rare-earth material buried at a proper depth in the semiconductor substrate, and reverse biasing to produce coherent light by pumping the rare-earth material at room temperature.

The semiconductor substrate comprises a doped P/N junction comprising a depletion layer, and the rare-earth material remains in the depletion layer when the semiconductor laser device is operating. Reverse biasing of the doped P/N junction produces coherent light by pumping the rare-earth material at room temperature, and the rare-earth material is

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buried within the doped P/N junction at a depth sufficient for defining an acceleration space between a region of the doped P/N junction that generates carriers when the rare-earth material is being pumped. This acceleration space allows the carriers to be accelerated before reaching the rare-earth material.

The location and extent of the depletion layer (within the doped P/N junction) which includes the rare-earth material is important; and the depth of the rare-earth material buried within the doped P/N junction to define an acceleration space is also important.

The depletion layer in a P/N junction is the area where free electrons have combined with holes to create an insulating barrier between the P and N regions. No carriers can cross the depletion layer until a bias voltage is applied to the P/N junction. When a positive bias voltage is applied, then the depletion layer becomes very thin so that carriers can easily cross the depletion layer. When the bias voltage is negative, then the depletion layer becomes wider and further acts as an insulator, making it more difficult for carriers to cross the depletion layer.

In the claimed invention, the depletion layer comprises at least one rare-earth material, such as erbium. The claims further recite that the rare-earth material is buried within the P/N junction at a depth sufficient for defining an acceleration space between a region of the P/N junction that generates carriers when the rare-earth material is being pumped. The acceleration space allows the carriers to be accelerated before reaching the rare-earth material.

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Reference is directed to FIGS. 11-13 of the Appellants' specification. FIG. 11 illustrates the depletion layer of a P/N junction. FIG. 12 is a graph showing the doping concentration of erbium versus depth in the depletion layer. FIG. 13 is a graph showing the depth of the erbium in the depletion layer versus the electrical field strength needed to achieve the necessary excited states of erbium.

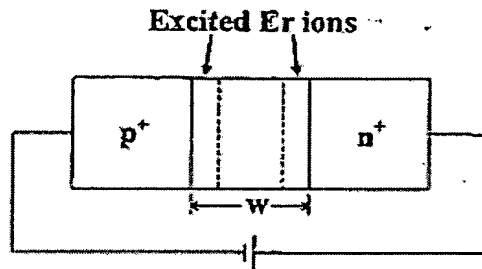


FIG. 11 from the Appellants' specification

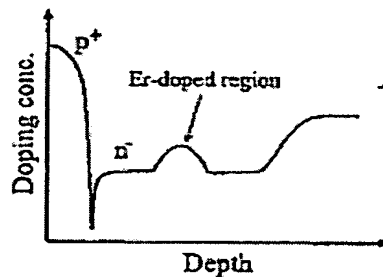


FIG. 12 from the Appellants' specification

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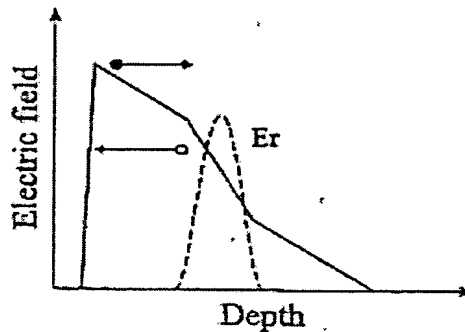


FIG. 13 from the Appellants' specification

As discussed above, the depletion layer becomes wider when a negative bias voltage is applied to the P/N junction. The Appellants noted on page 11, line 31 through page 12, line 13 of the specification that carriers do not have enough energy to pump the erbium ions when the P/N junction is reversed biased. The Appellants overcome this problem by providing a sufficient acceleration space for the carriers before they enter the erbium doped region of the P/N junction (page 12, lines 27-28).

Referring to page 9, lines 22-26 of the Appellants' specification, a sufficient acceleration space is to be provided to allow the carriers to be accelerated before reaching the erbium in the depletion layer. While a specific depth is not given, the Appellants respectfully submit that one skilled in the art can readily determine from the Appellants' specification that the depth will vary depending on the doping concentration of the erbium and the electrical field required to excite the erbium within the depletion layer, as best illustrated in FIGS. 12 and 13.

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(6) Issues

The issue presented on appeal is whether Claims 28, 31-38 and 41-47 are patentable under 35 U.S.C. § 103 over the Benton et al. patent (U.S. Patent No. 5,107,538) in view of the Franzo et al. article.

Alternatively, the issue presented on appeal is whether Claims 28, 31-38 and 41-47 are patentable under 35 U.S.C. § 103 over the Benton et al. patent (U.S. Patent No. 5,107,538) in view of the Coffa et al. article.

(7) Grouping of Claims

For the purposes of addressing the rejections under 35 U.S.C. § 103, the grouping of the claims is: Claims 28, 31-38 and 41-47 are together as a group.

(8) Arguments

I. The Claims

Independent Claim 28, for example, is directed to a semiconductor laser device for electro-optic applications comprising a semiconductor substrate, and a doped P/N junction integrated with the semiconductor substrate. The doped P/N junction comprises a depletion layer and has a shape defining a waveguide. The depletion layer comprises at least one rare-earth material for providing a coherent light source. The semiconductor laser device further comprises a biasing device connected to the doped P/N junction for reverse biasing thereof.

All of the at least one rare-earth material remains in the depletion layer when the semiconductor laser device is

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operating. Reverse biasing of the doped P/N junction produces coherent light by pumping the at least one rare-earth material at room temperature, and the at least one rare-earth material is buried within the doped P/N junction at a depth sufficient for defining an acceleration space between a region of the doped P/N junction that generates carriers when the at least one rare-earth material is being pumped. The acceleration space allows the carriers to be accelerated before reaching the at least one rare-earth material.

Independent Claim 38 is similar to independent Claim 28 except the preamble of the claim is directed to "a semiconductor laser device" instead of "a semiconductor laser device for electro-optical applications."

II. The Claims Are Patentable

The Examiner rejected independent Claims 28 and 38 over the Benton et al. patent in view of the Franzo et al. article. Alternatively, the Examiner also rejected independent Claims 28 and 38 over the Benton et al. patent in view of the Coffa et al. article. Both of these rejections will be addressed below in this section.

Referring now to the Benton et al. patent, FIG. 3 discloses an optical waveguide device that includes a silicon substrate **31**, an epitaxial silicon layer **32** on the substrate, an epitaxial silicon-germanium layer **33** on layer **32**, and an epitaxial silicon top cladding layer **34** on layer **33**. Layers **35**, **36** and **37** are metal contact layers that facilitate pumping of the device. The epitaxial silicon-germanium layer **33** has been doped with a rare-earth material, such as erbium. As correctly noted by the Examiner, the three-terminal optical

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waveguide device may also be configured as a two-terminal P/N structure. In addition, the Examiner correctly noted that Benton et al. fails to disclose that the optical waveguide device may be reversed biased to produce coherent light.

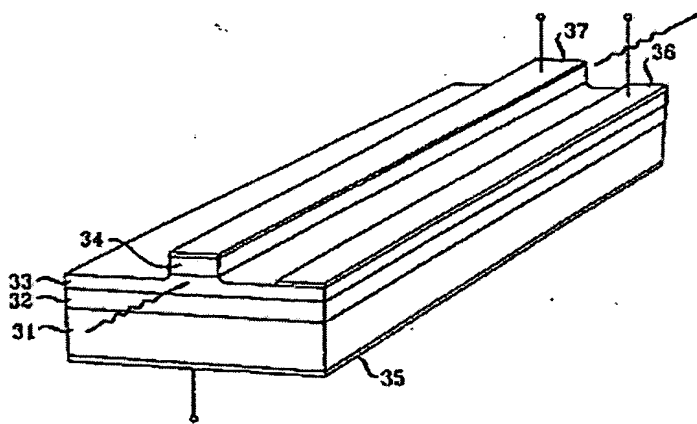


FIG. 3 from Benton et al.

The Examiner cited the Franzo et al. and Coffa et al. articles as disclosing the reverse biasing of a P/N junction doped with a rare-earth material, such as erbium. In particular, the doped P/N junction disclosed in these articles is for light emitting diodes (LED). The Examiner has taken the position that it would have been obvious to reverse bias the optical waveguide device in Benton et al. to more efficiently produce coherent light.

It appears that the Examiner is using hindsight reconstruction to modify Benton et al. in view of the Franzo et al. and Coffa et al. articles in an attempt to produce the claimed invention. As the Examiner is aware, there must be

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some suggestion or motivation, either in Benton et al. or in the knowledge generally available to one of ordinary skill in the art, to modify Benton et al. to include reverse biasing of the erbium doped P/N junction at room temperature. However, the Appellants respectfully submit that the selective modification of Benton et al. in view of the Franzo et al. and Coffa et al. articles are not properly combinable.

The Appellants respectfully submit that operation of a doped P/N junction as an LED which produces incoherent light is notably different than operating a rare-earth material doped P/N junction as a laser device which produces coherent light. In fact, one of the inventors, Salvatore Coffa, is a joint author of one of the prior art references, and has recognized this problem in the present invention. In other words, the behavior of a rare-earth material in a doped P/N junction is very dependent on the semiconductor substrate, and the requirements to achieve laser emission are much more stringent than those to achieve an incoherent light emission as in an LED. In Benton et al., the optical waveguide device including a doped erbium layer is generally discussed - and only discloses in the last sentence of the detailed description (column 4, lines 66-68) that the optical waveguide device may be used as a laser or LED.

Moreover, even though Benton et al. discloses that the optical waveguide device may be configured to include a two-terminal P/N junction, there is no mention of doping the depletion layer of the P/N junction so that all of the erbium remains in the depletion layer when the optical waveguide device is operating, as in the claimed invention.

In the optical waveguide device of Benton et al.,

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severe, non-radiated decay processes for erbium in silicon make it difficult to use erbium excitation by electron-hole pairs to fabricate an injection laser at room temperature. For example, in column 3, lines 44-50 of Benton et al., the disclosed laser was operated at 4.2K when data related thereto was collected. The only reference to operating the laser at room temperature is made in a generalized statement on line 50 that the collected data is expected to be substantially similar at room temperature.

Erbium excitation by hot carriers in a reverse biased P/N junction thus allows light emission to be achieved at room temperature, as disclosed in the Franzo et al. and Coffa et al. articles. However, as noted above, Franzo et al. and Coffa et al. refer to LEDs, i.e., devices in which incoherent light is generated. To obtain a coherent emission, i.e., a laser emission, an efficient electrical excitation has to be accompanied by the inversion of the optically active ions (so that a gain can be achieved) and by a reduction of the overall losses (so that a net gain can be achieved).

These requirements cannot be achieved by simply using erbium doping in a reversed biased P/N junction as suggested by the Examiner. The present invention thus provides an approach to meet these requirements to achieve laser action by tailoring the doping of the rare-earth material and the device structure itself.

For example, when the laser device of the present invention is operated, all of the ions of the rare-earth material are within the depletion layer of the P/N junction, as recited in independent Claims 28. This avoids rare-earth material ions from being left outside of this region, and

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hence, all of the rare-earth material ions can be pumped by hot carriers which are only present in the depletion layer. It should be noted that leaving some of the rare-earth material ions outside of the depletion layer would not produce any significant effect on an LED. On the other hand, this can kill laser action since the rare-earth material ions outside the depletion layer would be left in the ground state, and hence, they would absorb, rather than amplify, the coherent light.

In addition, some space needs to be left between the region of the maximum electrical field strength in the P/N junction (where the carriers are generated) and the depletion layer comprising the rare-earth material. This space allows proper acceleration of these carriers before they reach the ions of the rare-earth material. For example, 0.8 eV is needed to excite erbium ions from the ground state to the first excited state. Failing to meet this condition will produce a dark region in the center of the depletion layer, where erbium ions will not be pumped since the energy of the carriers will not be sufficient. Once again, these erbium ions would be left in the fundamental state and will absorb, rather than amplify, the coherent light.

The Appellants respectfully submit that there is no proper motivation or suggestion in the prior art to modify the optical waveguide device in Benton et al. so that it is reversed biased, and that all of the erbium in the P/N junction remains in the depletion layer thereof when the optical waveguide device is operated as a laser at room temperature, as in the claimed invention. This is particularly so since the Franzo et al. and Coffa et al.

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articles are directed to LEDs, where it is not critical to the operation of an LED if some of the rare-earth materials are outside of the depletion layer. Therefore, the prior art references do not teach or suggest such a combination.

Accordingly, it is submitted that independent Claim 28 is patentable over Benton et al. in view of the Franzo et al. article and the Coffa et al. article. Independent Claim 38 is similar to independent Claim 28. It is also submitted that independent Claim 38 is patentable over the prior art references. In view of the patentability of independent Claims 28 and 38, it is submitted that their dependent claims which recite yet further distinguishing features of the invention are also patentable. These dependent claims need no further discussion herein.

CONCLUSIONS

In view of the foregoing arguments, it is submitted that all of the claims are patentable over the prior art. Accordingly, Appellants respectfully request that all of the rejections be reversed.

Respectfully submitted,



MICHAEL W. TAYLOR
Reg. No. 43,182
Allen, Dyer, Doppelt, Milbrath
& Gilchrist, P.A.
255 S. Orange Avenue, Suite 1401
Post Office Box 3791
Orlando, Florida 32802
407-841-2330

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CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Mail Stop Appeal Brief-Patents, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on this 8 day of June, 2004.

Kristin Shanski

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APPENDIX INCLUDING THE CLAIMS ON APPEAL
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28. A semiconductor laser device for electro-optic applications comprising:

a semiconductor substrate;

a doped P/N junction integrated with said semiconductor substrate, said doped P/N junction comprising a depletion layer and having a shape defining a waveguide, said depletion layer comprising at least one rare-earth material for providing a coherent light source, all of said at least one rare-earth material remaining in said depletion layer when the semiconductor laser device is operating; and

a biasing device connected to said doped P/N junction for reverse biasing thereof to produce coherent light by pumping said at least one rare-earth material at room temperature;

said at least one rare-earth material being buried within said doped P/N junction at a depth sufficient for defining an acceleration space between a region of said doped P/N junction that generates carriers when said at least one rare-earth material is being pumped, the acceleration space allowing the carriers to be accelerated before reaching said at least one rare-earth material.

31. A semiconductor laser device according to Claim 28, wherein said at least one rare-earth material comprises erbium.

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32. A semiconductor laser device according to Claim 28, further comprising a protective layer partially on said doped P/N junction to delimit sides of the waveguide, said protective layer having a lower dielectric constant than a dielectric constant of said doped P/N junction.

33. A semiconductor laser device according to Claim 28, further comprising a buried reflecting layer to delimit a bottom of the waveguide.

34. A semiconductor laser device according to Claim 28, wherein said semiconductor substrate comprises a silicon on insulator (SOI) substrate.

35. A semiconductor laser device according to Claim 28, further comprising an epitaxial layer on said semiconductor substrate.

36. A semiconductor laser device according to Claim 28, wherein said doped P/N junction is stacked so that the shape of the waveguide is a ribbed elongated structure projecting from a surface of said semiconductor substrate.

37. A semiconductor laser device according to Claim 28, wherein said semiconductor substrate comprises silicon.

38. A semiconductor laser device comprising:
a semiconductor substrate;
a doped P/N junction integrated with said semiconductor substrate, said doped P/N junction comprising a

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depletion layer and having a shape defining a waveguide, said depletion layer comprising at least one rare-earth material for providing a coherent light source, and all of said at least one rare-earth material remaining in said depletion layer when the semiconductor laser device is operating; and
a biasing device connected to said doped P/N junction for reverse biasing thereof to produce coherent light from the coherent light source by pumping said at least one rare-earth material;

said at least one rare-earth material being buried within said doped P/N junction at a depth sufficient for defining an acceleration space between a region of said doped P/N junction that generates carriers when said at least one rare-earth material is being pumped, the acceleration space allowing the carriers to be accelerated before reaching said at least one rare-earth material.

41. A semiconductor laser device according to Claim 38, wherein said at least one rare-earth material comprises erbium.

42. A semiconductor laser device according to Claim 38, further comprising a protective layer partially on said doped P/N junction to delimit sides of the waveguide, said protective layer having a lower dielectric constant than a dielectric constant of said doped P/N junction.

43. A semiconductor laser device according to Claim 38, wherein said doped P/N junction is stacked so that the

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shape of the waveguide is a ribbed elongated structure projecting from a surface of said semiconductor substrate.

44. A semiconductor laser device according to Claim 38, wherein said semiconductor substrate comprises a silicon on insulator (SOI) substrate.

45. A semiconductor laser device according to Claim 38, further comprising an epitaxial layer on said semiconductor substrate.

46. A semiconductor laser device according to Claim 38, further comprising a buried reflecting layer to delimit a bottom of the waveguide.

47. A semiconductor laser device according to Claim 38, wherein said semiconductor substrate comprises silicon.